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Carderock Division
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Seaplane Economics: A quantitative cost comparison of seaplanes and land planes for Sea Base operations

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Abstract

The last U.S. military use of seaplanes was in the 1950s, but the emergence of the Sea Base concept has created requirements that seaplanes could fulfill. This study examined whether there is an economic justification for using seaplanes, the method being a quantitative cost comparison between existing conventional fixed-wing aircraft (land planes) operating from an air base and concept seaplanes operating from a Sea Base. Using published current and historical data a total cost per flight hour was determined for both land planes and seaplanes. This hourly rate included crew salary, procurement, maintenance, and fuel costs for both cases. The development cost was also included in the total hourly rate for seaplanes. These rates were then used to analyze specific missions comparing total cost, fuel usage, and response time for the land plane and seaplane scenarios. The analysis showed that the seaplane scenario was generally more economical and used less fuel as the land air base distance became greater than 400 nautical miles. The response time was always quicker for the seaplane scenario. The conclusion is that there is a clear economic justification for use of seaplanes for Sea Base operations.

Acknowledgements

This report is the culmination of work conducted by students hired under the National Research Enterprise Intern Program sponsored by the Office of Naval Research. This program provides an opportunity for students to participate in research at a Department of Navy laboratory for 10 weeks during the summer. The goals of the program are to encourage participating students to pursue science and engineering careers, to further education via mentoring by laboratory personnel and their participation in research, and to make them aware of Navy research and technology efforts, which can lead to future employment.

At the Naval Surface Warfare Center Carderock Division, the single largest employer of summer interns is the Center for Innovation in Ship Design (CISD), which is part of the Ship Systems Integration and Design Department. The intern program is just one way in which CISD fulfils its role of conducting student outreach and developing ship designers.

The student team consisted of:

Tom Denz

Rajeev Shrestha

Stephanie Smith

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Introduction

This study was conducted to perform a quantitative cost comparison between using existing conventional fixed wing aircraft and new seaplanes for U.S. Navy Sea Base operations. The purpose was to determine if there is economic justification for the Navy to fund and develop a new seaplane to support Sea Base operations. Seaplanes could be designed in different configurations and could be used for a variety of missions. This study focuses on a seaplane with a capability similar to a C-130J cargo aircraft with a 44,000 lb payload capacity and a 2,000 nautical mile range. The cost comparison was performed using hourly rates for operating several conventional aircraft and a new seaplane. Break-even flight distances were then calculated to determine when the costs for using conventional aircraft start to exceed that for using a seaplane. In addition, specific sample missions were defined and analyzed to determine and compare their costs.

Previous studies on seaplanes have been performed (see References). Issues regarding seaplane design and integration with a Sea Base have already been addressed. An economic study has also been done to compare the cost of supplying a Sea Base from CONUS using conventional airlift and high-speed sealift. It was found that even if a new high-speed sealift vessel had to be developed at a cost of around a billion dollars, it would still be less expensive to ship large quantities of logistics by sea than airlifting it with cargo aircraft[1]. This particular seaplane economics study, however, focuses more on the cost of performing operations near the Sea Base with either land based or amphibious airlift.

Background

A seaplane is a fixed wing aircraft designed to take off and land on water. As a result, it can provide support at ocean locations as well as on lakes and rivers. A Sea Base can be thought of as a collection of ships at a common location, typically 25 to 250 nautical miles off shore. It may involve new design ships and floating platforms (Figure 1). It may or may not have an aircraft carrier associated with it. A Sea Base has the great advantage of being mobile. In addition, the offshore location of a Sea Base may provide a greater degree of safety for the personnel and equipment associated with it than could be achieved at some land locations. Sea Bases can potentially be positioned at an optimum location with respect to a theater of operation. Logistics might be stored with the ships and platforms of the Sea Base and then deployed to a land location by aircraft or transport ships.

Role in the Sea Base

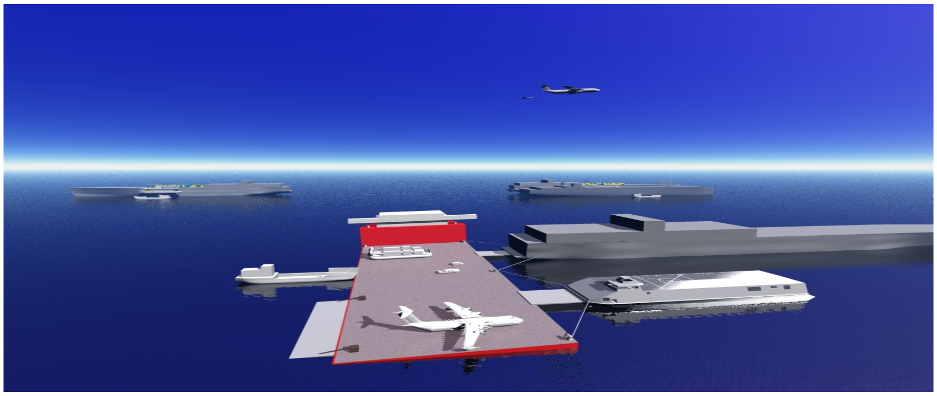

Figure 1: An artist's rendering of a seaplane mated with a Sea Base[2]

A seaplane fulfills an extremely useful role in Sea Base operations. It does not need a conventional runway to land. It can fly directly into and out of the Sea Base and provides direct support to the littoral area. Conventional aircraft do not have the capability of landing at a Sea Base. While a C-130 cargo aircraft has been landed and taken off from an aircraft carrier, such operations are not considered routine. In addition, an aircraft carrier is not meant to handle logistics. It is put to better use carrying and servicing combat aircraft.

Even if a new floating platform were designed to accommodate fixed wing cargo aircraft, it would have to be very large. Aircraft carrier lengths on the order of 1,000 ft are common. Something even larger would probably be needed if conventional aircraft were going to be landed at a Sea Base. Otherwise, use of conventional aircraft at a Sea Base might require some type of airdrop capability. This situation would then involve at sea recovery of payloads in the water. Some extra procedures and possibly additional equipment would be required. Picking up a load from a Sea Base with a conventional aircraft would be even more difficult, if not prohibitively impractical. Helicopter flights into and out of a Sea Base are certainly possible. A helicopter, however, is much more limited both in terms of the payload it can carry and its range. Logistics handling with helicopters would then be more difficult than with the larger seaplanes.

Seaplanes can provide logistics support for force closure operations. They can also perform other missions. Some of these scenarios might include in-flight refueling, maritime patrol/search and rescue, and casualty evacuation. The seaplane adds a particularly useful airlift capability to a Sea Base. A Sea Base will probably need ships that are specifically designed for storing large quantities of supplies, selective loading and offloading, roll-on/roll-off capabilities, and the ability to dock or mate with other ships. The ability to fly into and out of a Sea Base would complement its other features. Because of the larger quantities of logistics involved, the capability provided by larger seaplanes, rather than just helicopters, becomes that much more important.

History of Naval Use

The U.S. military has used seaplanes before, but not recently. The last U.S. military seaplane use was from World War II and into the 1950s. Seaplanes were eventually phased out after the war. The increase in the number of suitable airfields on land influenced their decommissioning.

Figure 2: ShinMaywa US-1A

Two of the last military seaplanes were the Martin JRM-3 Mars and the Convair R3Y Tradewind. These aircraft were comparable in size and payload capability to the conventional C-130. While the U.S. military may not be using seaplanes, they are available in the commercial market. Japan's ShinMaywa Industries, Ltd. has a large seaplane for maritime patrol and search and rescue operations. Its US-1A model (Figure 2) has been available since the mid 1970s. Canada's Canadair CL 415 is another example from the mid 1990s. The Beriev Aircraft Company from the Ukraine produces a number of seaplanes including the A-40 from the 1980s and the BE-200 from the 1990s. These seaplanes are examples of larger aircraft and are configured with jet engines. Larger capacity seaplanes are currently produced. The technology is available. They are just not in service with the U.S. military at this time.

Types of Seaplanes

Figure 3: STOL CH 701 float plane

There are several different configurations of seaplanes. One is the float plane (Figure 3). It looks like a conventional land plane with floats or pontoons for landing. Float planes are usually smaller and have lower aerodynamic performance.

Figure 4: The Ukrainian Beriev A-40 Albatross flying boat

Another seaplane configuration is the flying boat (Figure 4). Its fuselage is shaped like a boat hull. It can take off and land on water directly on the hull section. These planes tend to be larger than float planes. The hull must be stronger, and therefore heavier, to withstand the extra loads. The use of composite materials in a new design might help to minimize the additional weight needed for strength. Composites would also provide better resistance to corrosion from salt water, but may suffer from water absorption.

Figure 5: Canadair's amphibious CL-415 Bombardier with retractable landing gear

An amphibious aircraft is the third configuration of seaplane (Figure 5). It can take off and land on water or the ground. It usually has a boat hull, like the flying boat configuration, and a landing gear system varying from beachable to full runway compatibility. The landing gear adds to the weight and complexity of the aircraft, as well as a possible increase in drag. It is the fully amphibious type of seaplane that was considered in this study.

Equivalent Land-based Aircraft

Figure 6: The C-5 Galaxy

The conventional fixed wing aircraft considered in this study include the C-5, C-17, and C-130. These cargo aircraft are commonly used in the U.S. military. The C-5, shown in Figure 6, is the largest US military cargo plane currently in use. It can provide strategic or global airlift. Appendix 1 contains its specifications.

Figure 7: The C-17A Globemaster II

The C-17, shown in Figure 7, is a newer strategic airlifter. The C-17 was designed to be able to land at more runways than the C-5, and can therefore provide forward support at more locations. Appendix 1 contains its specifications.

Figure 8: The C-130 performing a low altitude parachute drop

The C-130 is typically used for intra-theater operations (Figure 8). It has been in use since the 1950s by over sixty countries. There are more than seventy configurations of the C-130 (Lockheed Martin). It can land at numerous airfields and is suited for forward troop support. The Low Altitude Parachute Extraction System (LAPES) adds to an aircraft's ability to provide forward support. The C-130J-30, a stretched version of the C-130J, was used in this study for comparison purposes. Appendix 1 contains its specifications.

Weather Effects on Seaplanes

An amphibious seaplane operates from the land and the water. As a result, there could be additional weather factors that impact seaplane operations more than conventional aircraft operations. One difficult situation occurs when landing on a very smooth, or wave-less, water surface. While not obvious, such conditions can be dangerous to a seaplane pilot. The glassy water presents a uniform mirror-like appearance making it difficult to judge the height of the aircraft. Clouds reflected from the water surface could add to the visual confusion. In contrast, a runway on land provides better visual cues. There may also be features that the pilot can see with peripheral vision that make aircraft heights above the ground easier to judge. As a result of these factors, seaplane landing maneuvers may require extra training for the pilots in proper techniques. Extra instrumentation in the seaplane might help by providing a visual reference of the water surface, especially at night.

Besides extremely calm conditions, rough seas can be a limiting factor for seaplane takeoffs and landings. High sea states and rough wave conditions might make seaplane operations impossible. Adverse wave and swell patterns might not prohibit the use of a seaplane but could lead to increased accident rates. Additionally, floating debris can sometimes be hard to see and could also result in higher accident rates or seaplane damage.

The use of seaplanes will then result in additional costs to accommodate the ocean and water environment. While conventional aircraft are subject to limiting weather factors such as fog, rain, icing, and sand or dust storms in the desert, amphibious seaplanes could also be affected when supporting locations on land.

A new seaplane design can be expected to handle conditions through Sea State 5. The ShinMaywa seaplane has the capability to operate in thirteen-foot waves, which corresponds to a Sea State 5 condition[2]. The percentage of the time that the North Atlantic and North Pacific are in different sea states is shown in Table 1.

Sea State Number	Significant Wave Height (m)	NORTH ATLANTIC Percentage Probability of Sea State	NORTH PACIFIC Percentage Probability of Sea State
0-1 Calm	0 to 0.1 m	0.70%	1.60%
2 Smooth	0.1 to 0.5 m	6.80%	6.40%
3 Slight	0.5 to 1.25 m	23.70%	15.50%
4 Moderate	1.25 to 2.5 m	27.80%	31.60%
5 Rough	2.5 to 4 m	20.64%	20.94%
6 Very Rough	4 to 6 m	13.15%	15.03%
7 High	6 to 9 m	6.05%	7.60%
8 Very High	9 to 14 m	1.11%	1.56%
>8 Phenomenal	Over 14 m	0.05%	0.07%

Table 1: Annual sea state occurrences in the open ocean[3]

Conditions at Sea State 6 and above occur about 20 to 25 % of the time in these regions. Impacts to seaplane operations could occur during these periods requiring some type of workaround. Pictorial representations of sea states are shown in Figures 9 and 10 for the North Atlantic and North Pacific. They are snapshots of conditions on July 9, 2007.

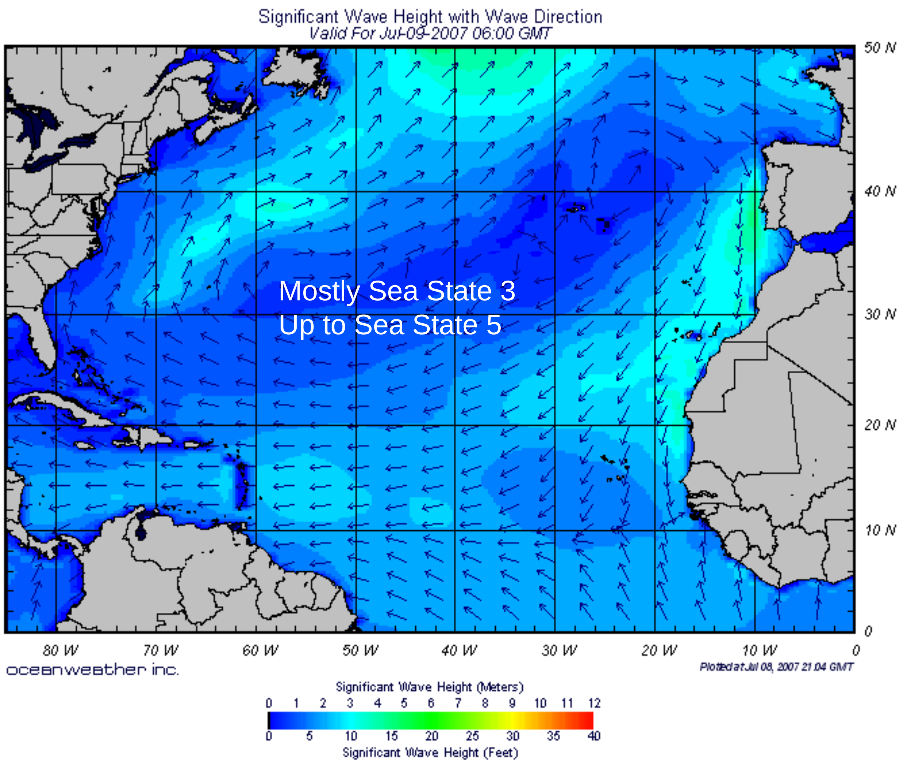

Figure 9: Sea conditions in the Atlantic Ocean[4]

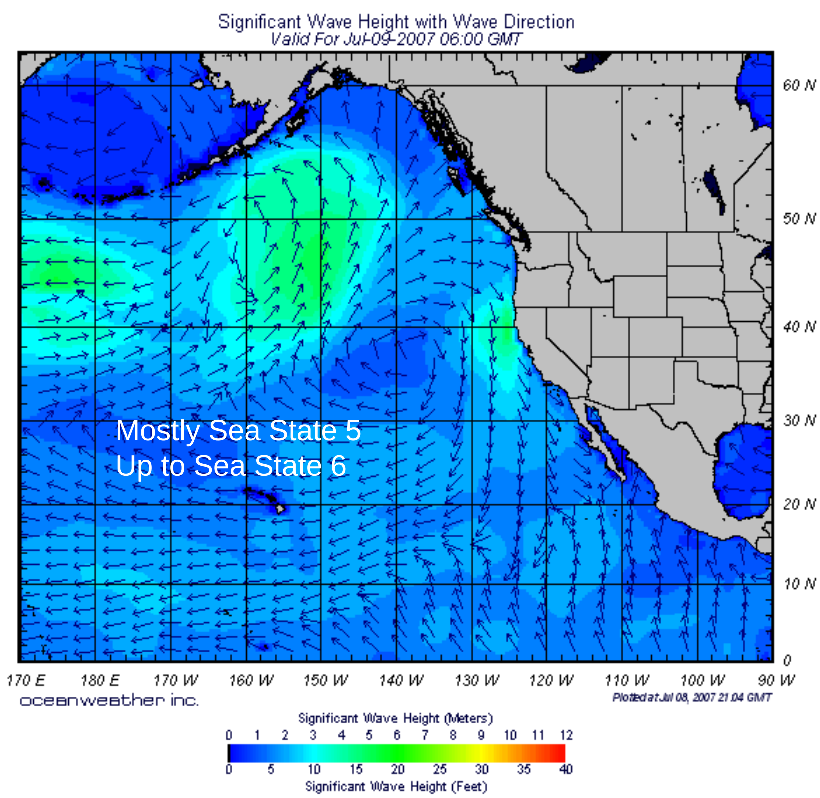

Figure 10: Sea conditions in the Pacific Ocean[4]

The extra costs that would occur because of additional training for seaplane operations and the ocean weather and water condition impacts have not been quantified. These considerations are qualitative in nature. It is still possible to make a quantitative comparison between seaplanes and conventional aircraft by looking at hourly rates for different planes.

Development of Hourly Rates

In order to quantitatively compare land planes and seaplanes (amphibious), total hourly rates were developed in dollars per flying hour per plane. The concept seaplane was defined as a fully amphibious version of the stretched C-130J Hercules with a payload of 44,000 lb and similar capabilities. For simplicity and as a start for analysis, the hourly rates were treated as constant for all flight conditions and mission requirements.

Land Planes

$$\frac{(Proc.\ per\ unit)}{(Service\ life\ hrs)} + (Hourly\ Oper.\ Cost) = Tot.\ Hourly\ Rate \qquad (1)$$

For land planes, the total hourly rate per flying hour was determined, as shown in Equation (1), to be the sum the aircraft's procurement and operational costs. The average service life was used to convert the procurement cost into an hourly figure. This study was constrained to existing land aircraft, hence development cost was not included in the total hourly rate for land planes. If new land planes were considered, then the cost analysis would be different.

Published average unit flyaway cost figures were used as the procurement cost per aircraft. These figures did not include weapons and armaments or test and evaluation expenditures. Aircraft reimbursable rates charged by the Air Force to the Department of Defense were used as estimates for hourly operational cost, which reflect the cost of fuel, depot maintenance and supplies, and personnel costs.

Seaplanes

$$\frac{R\&D}{(\#\ built)(Service\ life\ hrs)} + \frac{(Proc.\ per\ unit)}{(Service\ life\ hrs)} + Hourly\ Oper.\ Cost = Tot.\ Hourly\ Rate \qquad (2)$$

For seaplanes, the total hourly rate was determined using Equation (2). Similar to the land plane formula the rate included procurement and operational costs per aircraft for one flying hour. However, an additional cost for research and development was included in the total hourly rate for seaplanes.

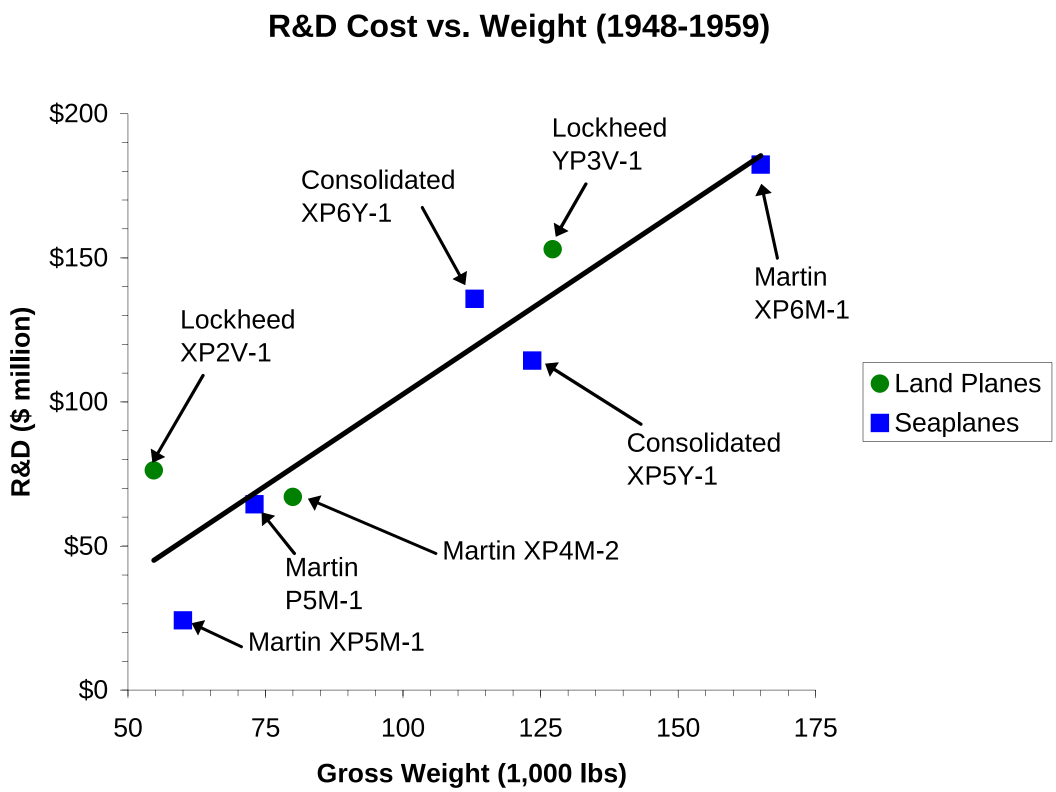

Figure 11: Historical data comparing development cost for land planes and seaplanes in 2007 dollars[5]

To estimate the development cost for seaplanes, historical data comparing land planes and seaplanes was used to determine the cost of developing a seaplane relative to a land plane of similar size. It was concluded from a 1964 Bureau of Naval Weapons report[5] comparing large land planes and large seaplanes from the immediate post-WWII era (Figure 11) that the development cost of similar sized land planes and seaplanes were equivalent. The data shows that there is a definite linear relationship between development cost and gross weight, and within the scope of that linearity, there is no difference between the cost of developing a land plane and a seaplane. Thus it was assumed that the development costs for more recent land planes could be used to estimate the development cost of a new seaplane.

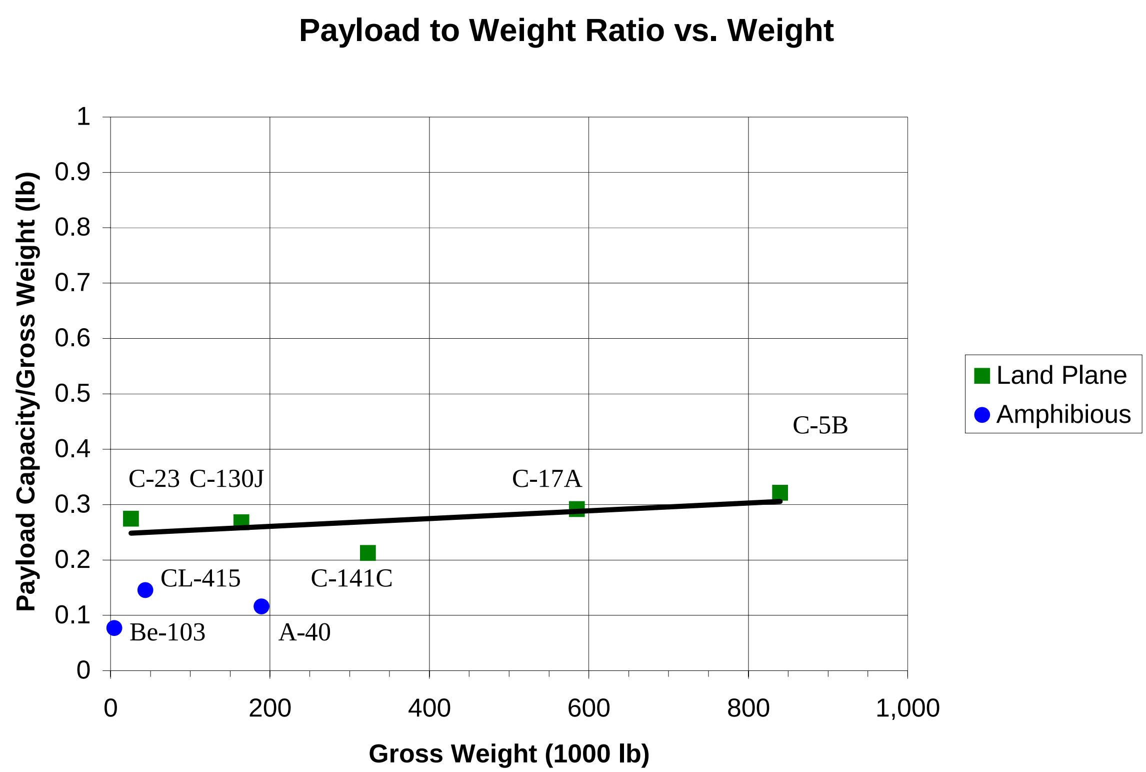

Figure 12: Payload capacity comparison between land planes and currently operating amphibious flying boats (see Appendices 8.1 and 8.2)

$$\frac{Amphibious\ \ payload}{Amphibious\ \ weight} = \frac{LandPlane\ \ payload}{LandPlane\ \ weight} - 0.1 \qquad \textbf{(3)}$$

Before the development cost of an amphibious seaplane could be calculated, the weight of the aircraft had to be estimated. Payload data for land planes and amphibious seaplanes (Figure 12) revealed that amphibians had a maximum payload to gross weight ratio that was approximately 0.1 smaller than for conventional aircraft. Using a desired payload equal to the payload of the C-130J-30 (44,000 lb) in Equation (3), a gross weight of 261,449 lb was calculated for a new design amphibious seaplane.

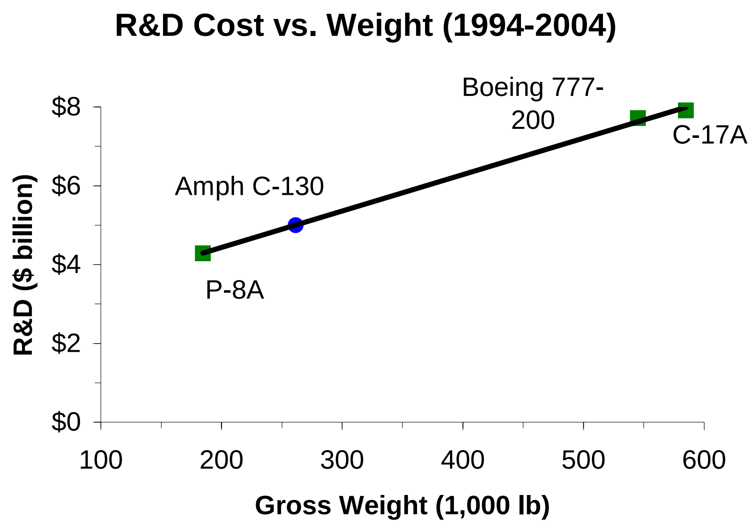

Figure 13: Published development cost for current land planes in 2007 dollars[6,7,8]

$$Seaplane\ R\ \&\ D\ Cost = \left(\frac{\$0.0093\ billion}{1{,}000\ lb}\right) * weight + \$2.58\ billion \tag{4}$$

Using this estimated gross weight and the earlier presumption that development cost is comparable for land planes and seaplanes, the development cost for a seaplane (amphibious) was calculated to be approximately $5.0 billion from Equation (4). This value was interpolated from the published cost data for several recent conventional aircraft development projects shown in Figure 13.

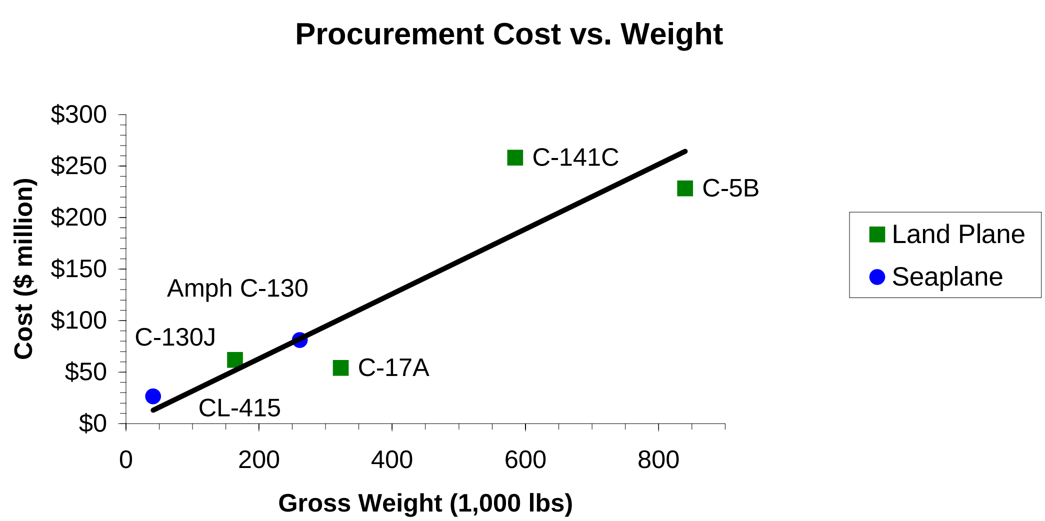

Figure 14 Published procurement cost for land planes and seaplanes in 2007 dollars[9,10,11]

$$Seaplane\ \text{Pr}ocurement\ Cost = \left(\frac{\$0.31\ million}{1{,}000\ lbs}\right) * weight \tag{5}$$

As can be seen in Figure 14, procurement cost is also a linear function of weight. Although there is only one data point for a seaplane (Canadair's amphibious CL-415 which costs $26.3 million), it follows the same linear relationship of Equation (5). Thus it was concluded that the procurement cost of land planes and seaplanes were equivalent for comparable aircraft weights. This resulted in a procurement cost for a new seaplane of about $81 million per aircraft.

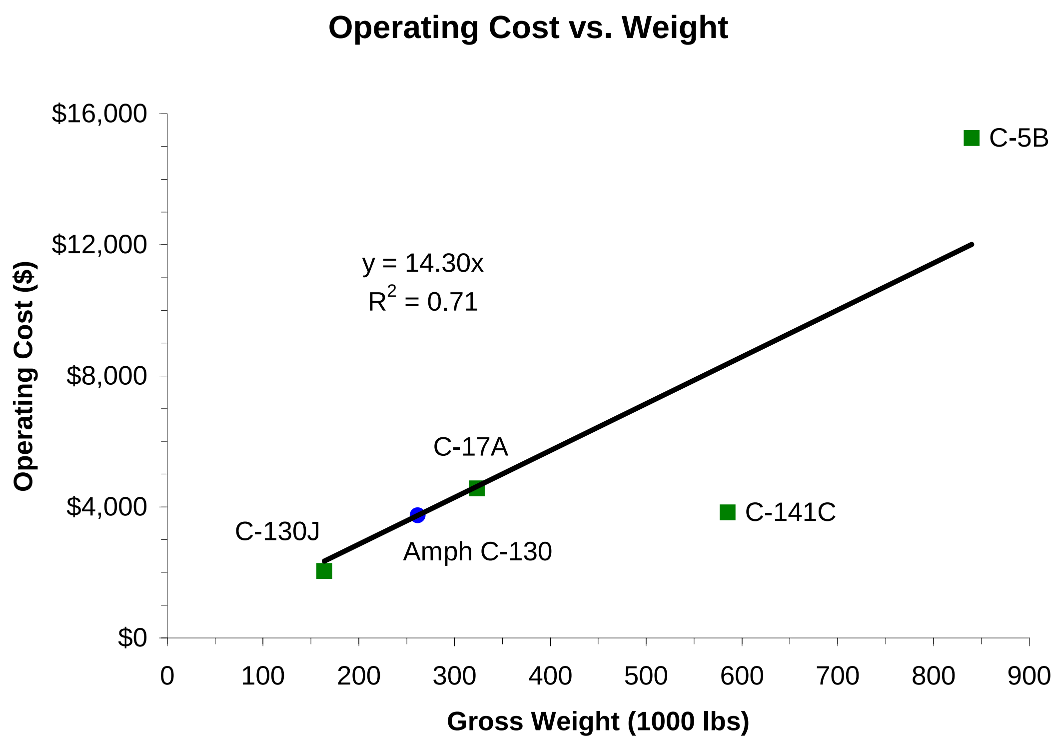

Figure 15: Average operating cost estimates for land planes in 2007 dollars[12]

$$Seaplane\ Operating\ Cost = \left(\frac{\$14.30}{1{,}000\ lb}\right) * weight \tag{6}$$

The same reasoning was used for estimating the operating cost for seaplanes. Figure 15 shows that there is a linear relationship between average operating cost and gross weight for military cargo planes. Since there were no operating cost estimates available for large seaplanes, an assumption was made that they would follow the same relationship with weight as land planes. The uncertainty arising from this assumption is large but much smaller than the uncertainties in the Air Force operating cost estimates. Using Equation (6), the resultant operating cost for the amphibious seaplane is $3,739 per flying hour.

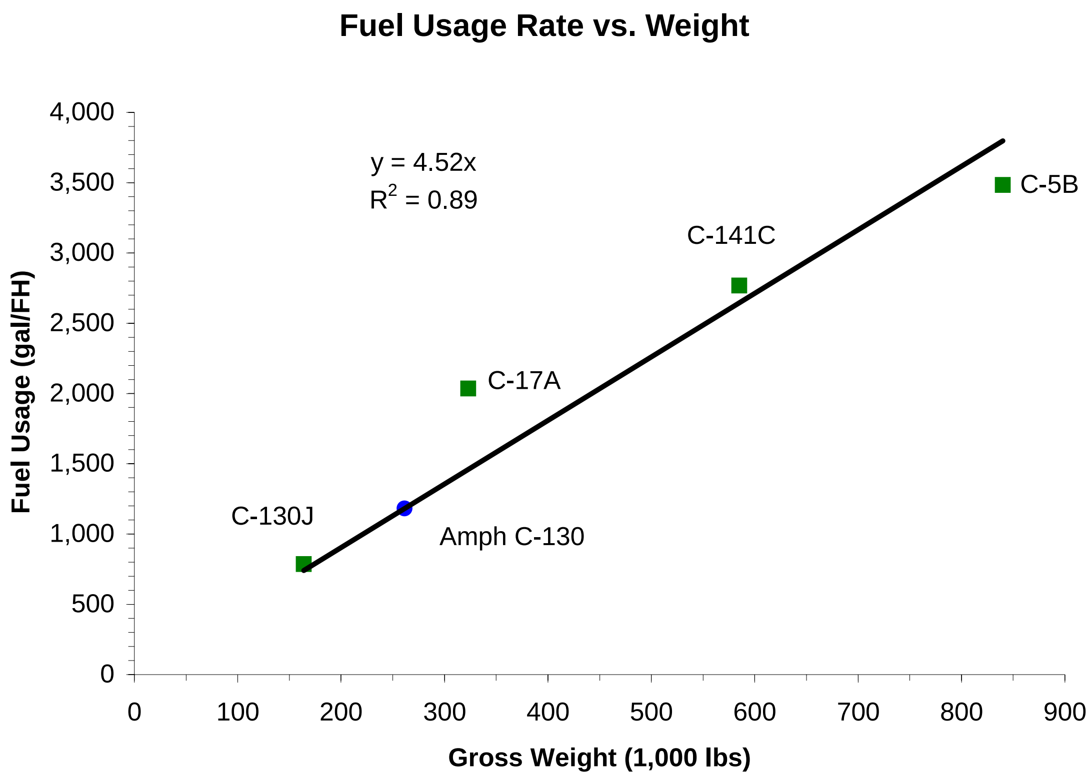

Figure 16: Estimated average fuel usage rates for land planes[13]

$$Seaplane\ \ fuel\ usage = 1.5 * \left(\frac{4.52\ gal/FH}{1{,}000\ lb} \right) * weight \tag{7}$$

Fuel usage rates for large cargo aircraft also show a strong linear relationship with gross weight (Figure 16). To estimate the relative fuel usage for seaplanes, historical data comparing aerodynamic drag of flying boats and land planes was consulted. According to a 1949 study, large seaplanes have on average 50% more drag than land planes of similar weight[14]. This would largely be due to the added drag from the marine subsystem and the hydrodynamic hull. Therefore, an amphibious seaplane would have 50% more drag than a land plane with the same gross weight, roughly translating to 50% more fuel usage. Using Equation (7), the seaplane would burn an average of approximately 1,773 gallons of fuel per flying hour.

Hourly Rates

The total hourly costs per aircraft are listed in Table 2. Assumptions were made that the service life for the C-130 size seaplane would be 30,000 hours and that only 50 would be built. This study was limited to a comparison between a new amphibious seaplane and the existing C-130J land plane. The hourly rate for the amphibious seaplane is approximately three times the hourly rate for the C-130J if development cost is ignored for the land plane.

	C-17A	C-5B	**C-130J**	**Amphibious Seaplane**
Gross Weight (1,000 lb)	585	840	164	261
Number Built	180	131	2,262	50
Service Life (hrs)	30,000	50,000	50,000	30,000
R&D Cost ($ billion)	$7.9	$10.4	$4.1	$5.0
Procurement Cost ($ million)	$258.09	$228.36	$61.87	$81.05
Operational Cost ($/hr)	$3,832	$15,255	$2,047	$3,739
Total Hr. Rate w/o R&D ($/hr) [Eq. 1]	$12,435	$19,822	**$3,284**	$6,440
Total Hr. Rate W/R&D ($/hr) [Eq. 2]	$13,900	$21,404	$3,555	**$9,774**
Fuel Rate (gal/hr)	2,767	3,483	786	1,773

Table 2: Summary of cost figures in 2007 dollars. In bold are the figures used in the mission specific cost evaluation[10,12,13]

Mission Specific Cost Evaluation

Using the hourly rates from Table 2, a total cost comparison was performed between a land plane (C-130J-30) and a seaplane (amphibious C-130) for specific mission scenarios. The missions considered in this study were:

- force closure,
- in-flight refueling,
- maritime patrol/search and rescue, and
- casualty evacuation.

There are many other missions that can be performed by a seaplane but cannot be performed by land planes (fire fighting, submarine rescue and refueling, mine warfare, environmental cleanup, etc.). Only missions that could be performed by both seaplanes and land planes were considered.

$$(\#\,Land\ Plane\ Sorties)\left(\frac{Distance}{Speed}\right)(Hourly\ Rate) = Land\ Plane\ Cost \qquad (8)$$

$$(\#\,Seaplane\ Sorties)\left(\frac{Distance}{Speed}\right)(Hourly\ Rate) = Seaplane\ Cost \qquad (9)$$

The total costs were calculated using Equations (8) for the land plane scenario and Equation (9) for the seaplane scenario. The number of sorties and the distance traveled

varied depending on the mission. The speed and the hourly rates\were kept constant throughout the different missions. The speed and range of the seaplane (see appendix) was assumed to be 90% and 75%, respectively, of the land plane[14].

Force Closure

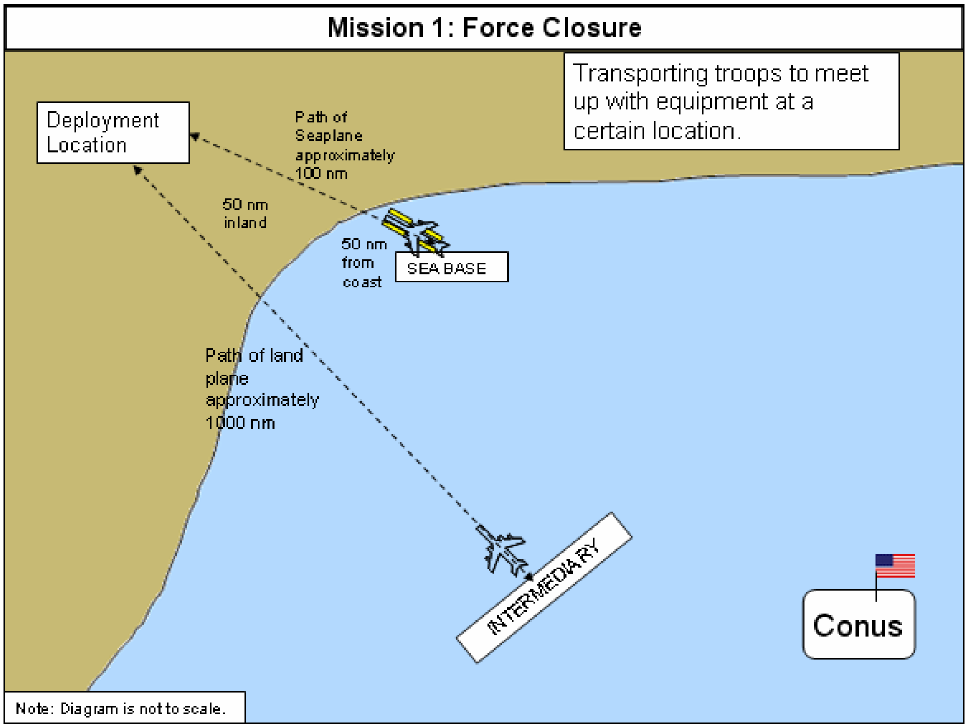

Figure 17: Force closure event model

Force closure involves the transfer of troops and equipment to a certain location. Assumptions were made that for the seaplane scenario; the troops and equipments would already be at the Sea Base, which was a fixed 50 nm from shore, while the land plane would have to operate from an intermediary base. The mission objective was to transfer 3,000 troops (a brigade) and 3,500 tons of equipment from the base to a location 50 nm inland and then fly back to the base. Both the C-130J-30 and the seaplane can carry either 128 troops or 22 tons, so 184 sorties would be required for both scenarios. A tanker plane would do refueling when necessary.

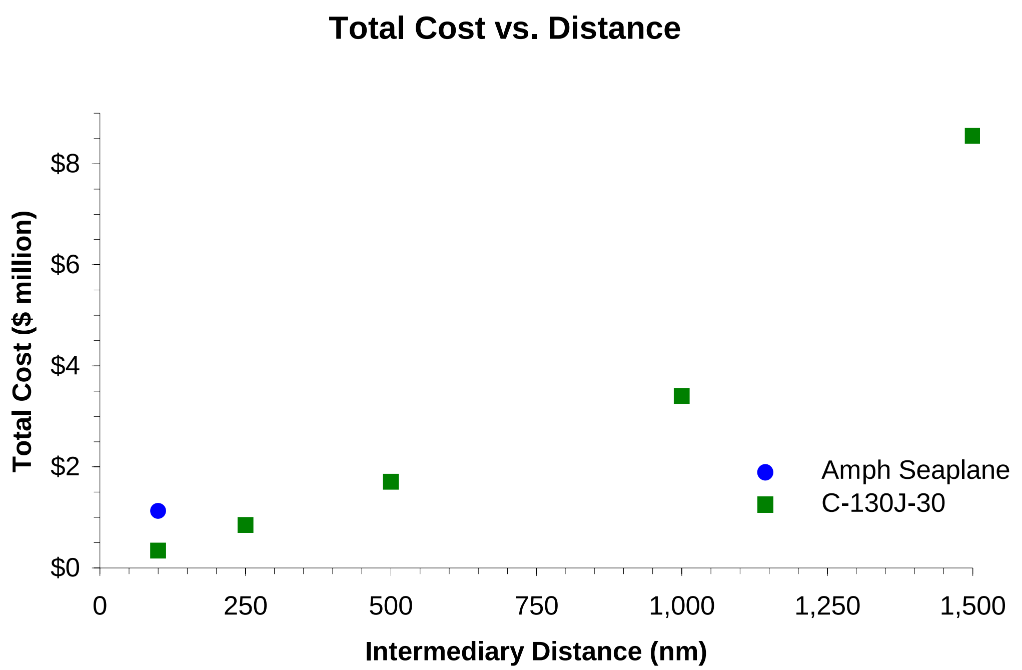

Figure 18: Total cost analysis for force closure

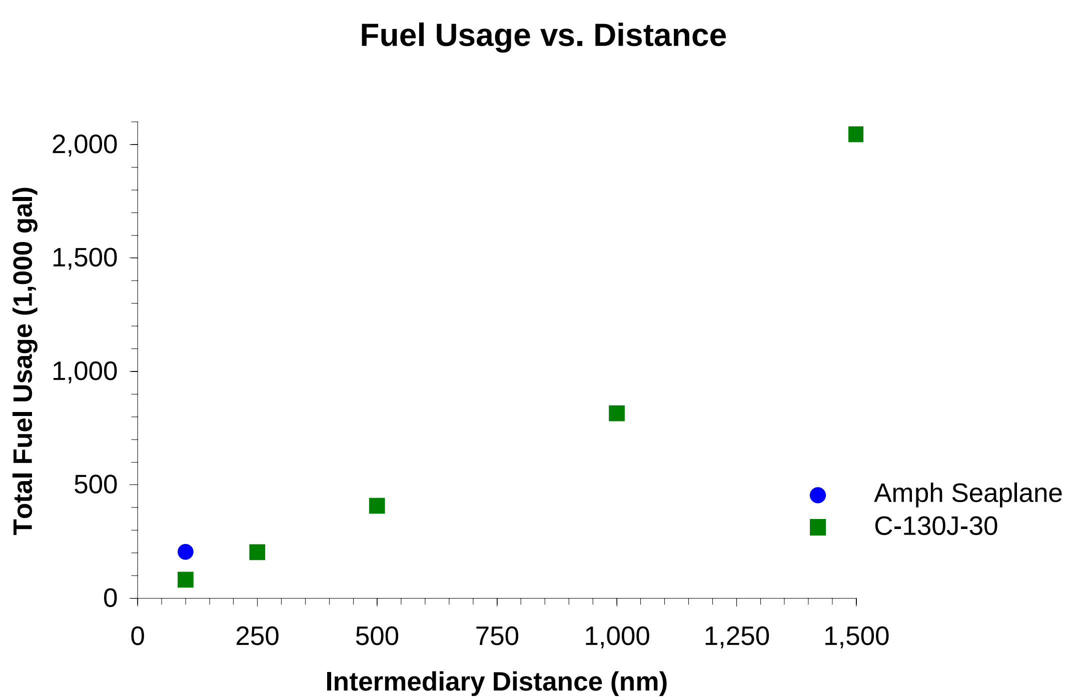

Figure 19: Total fuel usage comparison for force closure mission

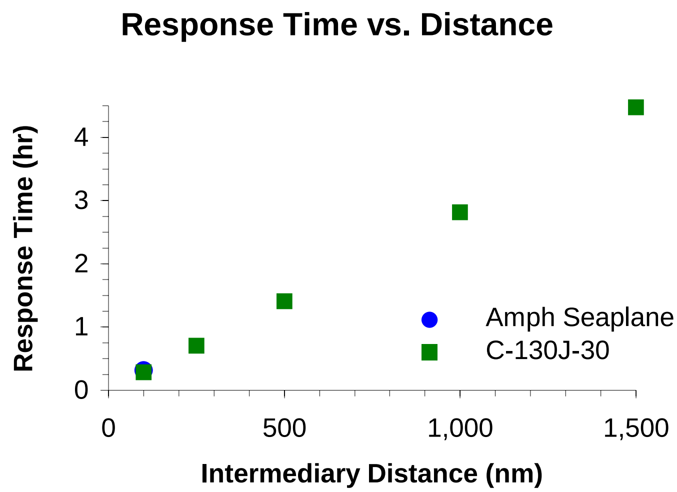

Figure 20: Response time comparison for force closure mission

The results of the cost analysis for the force closure mission in Figures 18, 19, and 20 reveal that the amphibious seaplane is more economical when the land plane intermediary distance is more than 330 nm. The seaplane uses less fuel if the intermediary is more than 250 nm away from the supported location. The savings are even greater if the location is beyond the range of the land plane and aerial refueling is needed. The seaplane has a quicker response time for intermediary distances greater than 150 nm.

In-flight Refueling

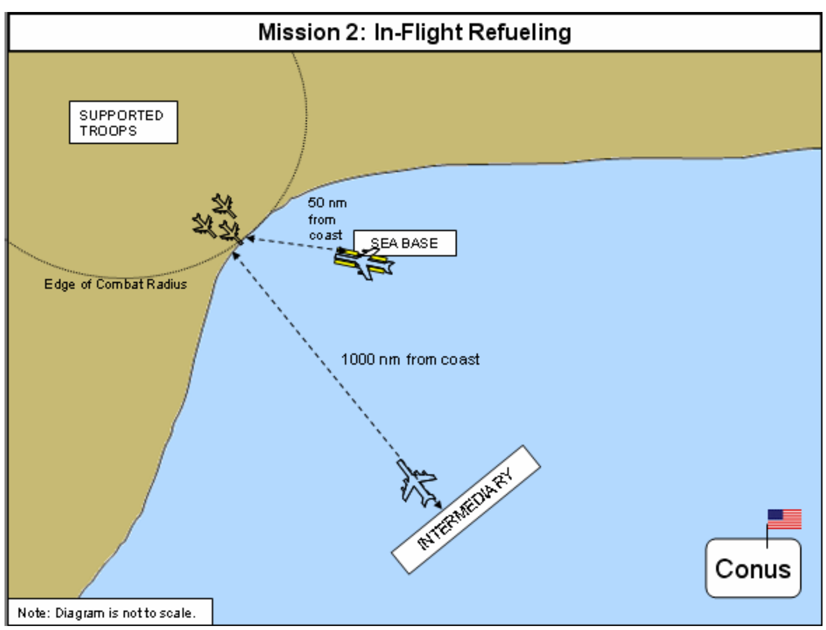

Figure 21: In-flight refueling event model

The in-flight refueling mission involves flying tanker planes from a base to the edge of the combat radius, refueling other aircraft, and returning to base. The amphibious tanker seaplane would operate from a Sea Base at a fixed distance of 50 nm from the combat radius while the conventional tanker plane would have to operate from an intermediary base. The objective of the mission would be to refuel 10 F-18F Hornets, a total fuel transfer of 100,000 lb. Three sorties would be required for both seaplane and land plane scenarios.

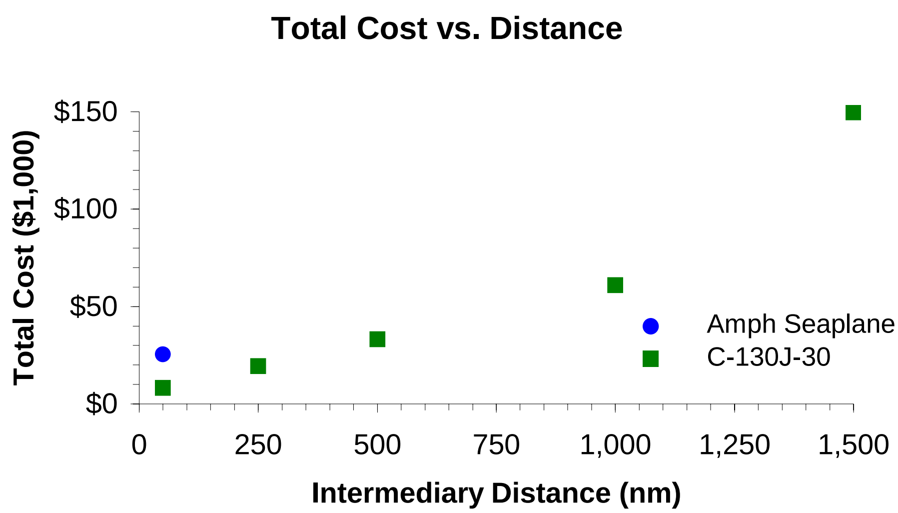

Figure 22: Result of cost analysis for in-flight refueling

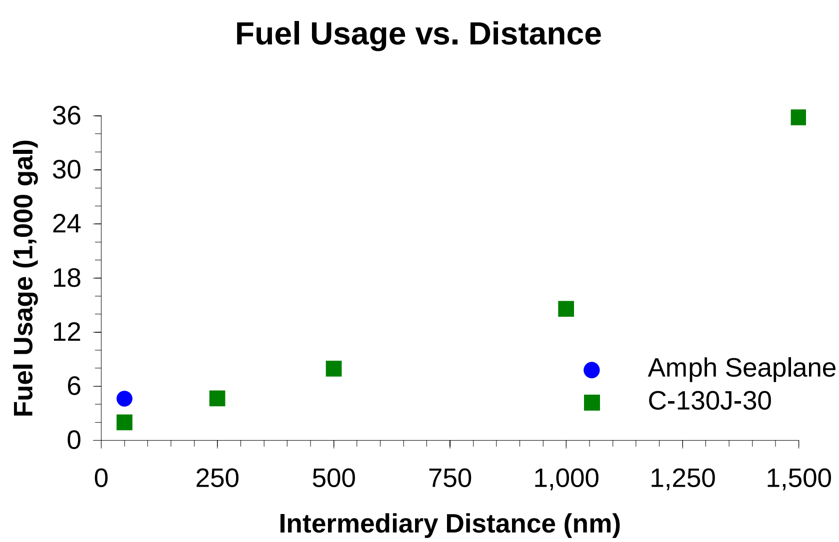

Figure 23: Tanker seaplane and tanker land plane fuel usage comparison for in-flight refueling mission

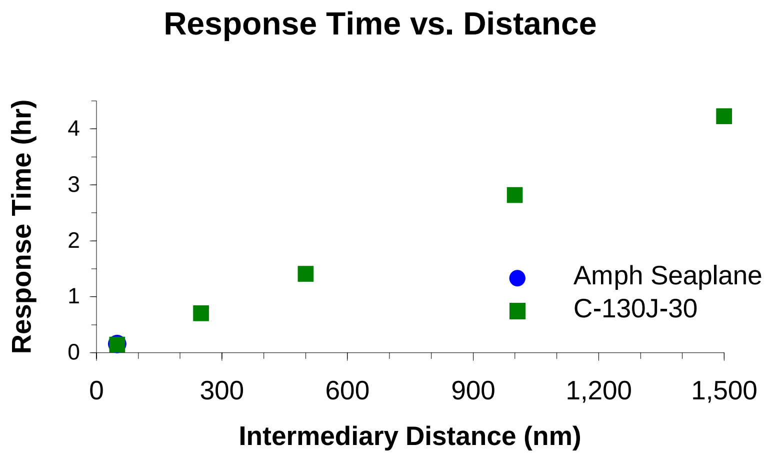

Figure 24 Response time comparison for in-flight refueling mission

The cost analysis for the in-flight refueling mission shown in Figures 22, 23, and 24 calculates that the amphibious seaplane is more economical than a land plane for intermediary distances greater than 400 nm. The seaplane uses less fuel if the intermediary is more than 250 nm away from the target location. The savings are even greater if the location is beyond the range of the land plane and aerial refueling of the conventional tanker aircraft itself is needed. The seaplane has a clear advantage in response time once intermediary distances are greater than 75 nm.

Maritime Patrol/Search and Rescue

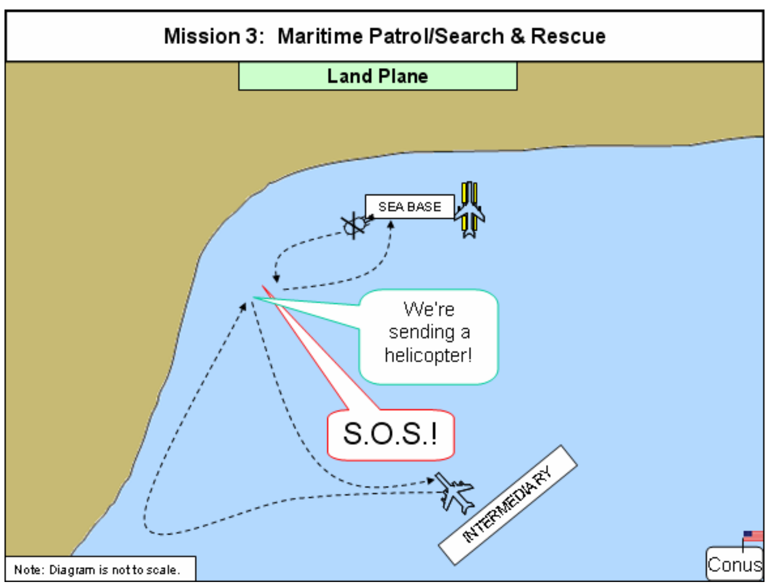

Figure 25: Maritime patrol/search & rescue event model: land plane

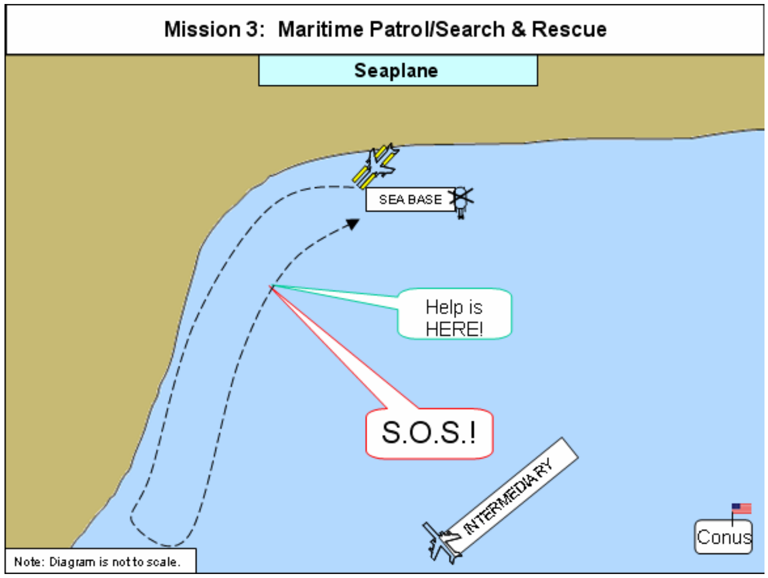

Figure 26: Maritime patrol/search & rescue event model: seaplane

This mission involves performing surveillance over an area, rescuing a castaway, and returning to base. The example seaplane scenario would require the aircraft (amphibious) to fly from the Sea Base to the patrol area (a fixed 50 nm), patrol a distance of 200 nm until a castaway is found 100 nm from the Sea Base, rescue the castaway, and then return to the Sea Base. The land plane scenario would require the aircraft (C-130J-30) to fly from an intermediary base to the patrol area and patrol the same distance. However, when the castaway is found the land plane would have to call a helicopter (UH-1N) from the Sea Base to rescue the castaway. The only distance that was varied in the analysis was the intermediary distance for the land plane scenario.

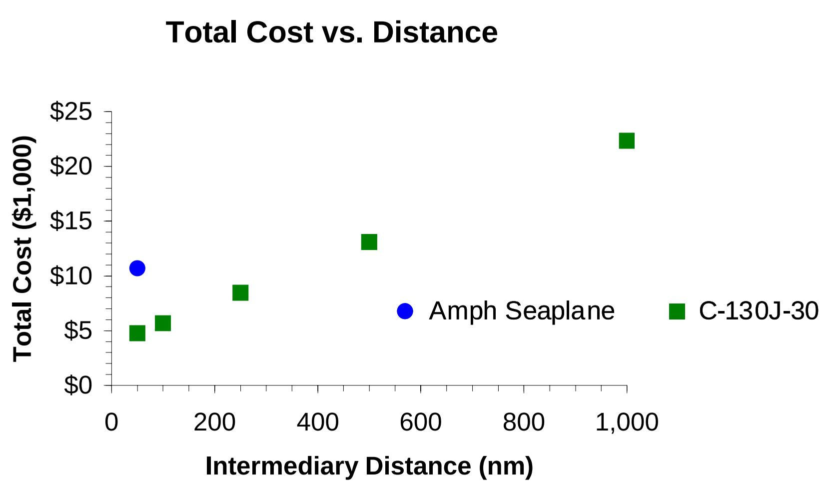

Figure 27:Total cost for maritime patrol/SAR mission

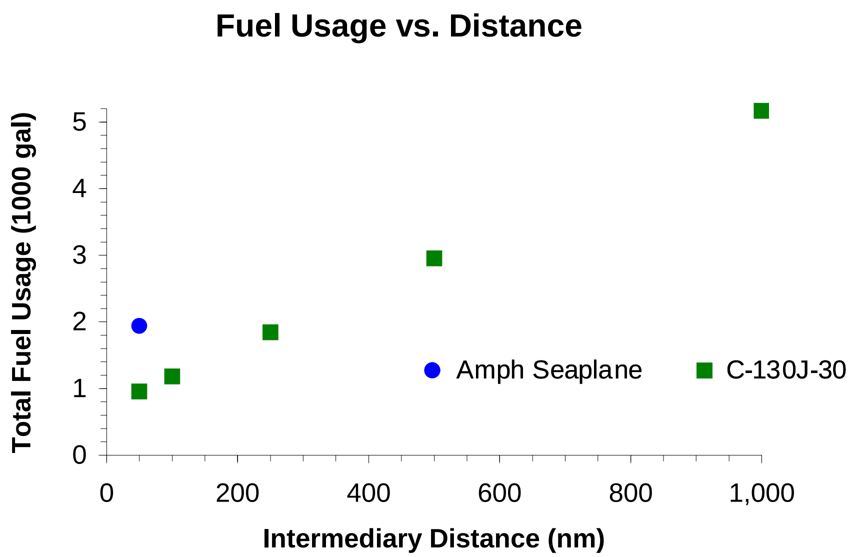

Figure 28: Total fuel usage comparison for maritime patrol/SAR mission

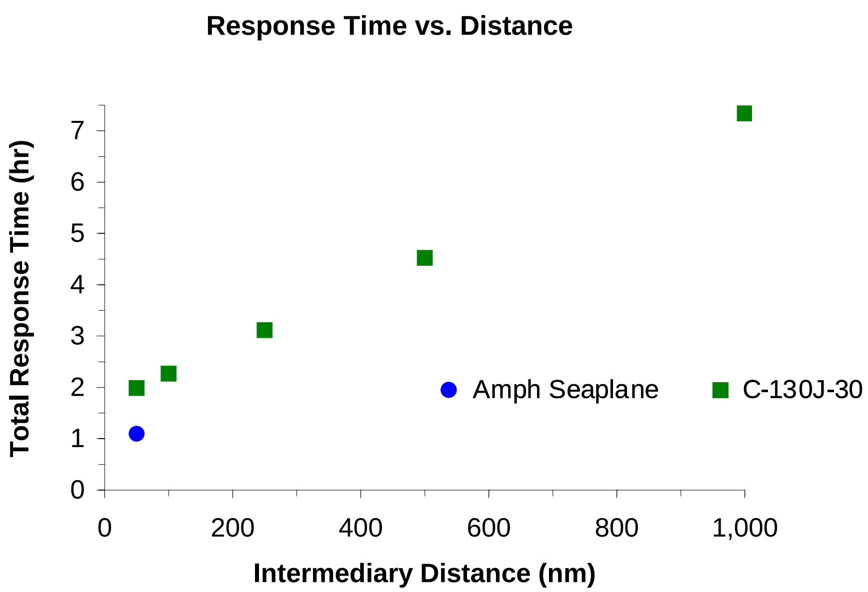

Figure 29: Response time comparison for maritime patrol/SAR mission

As shown in Figures 27, 28, and 29 for maritime patrol/SAR, the seaplane scenario is more economical than the land plane and helicopter scenario at intermediary distances of more than 410 nm. The seaplane uses less fuel if the intermediary is more than 250 nm away from the target location. Most importantly, the seaplane has a clear advantage in response time for all distances.

Casualty Evacuation

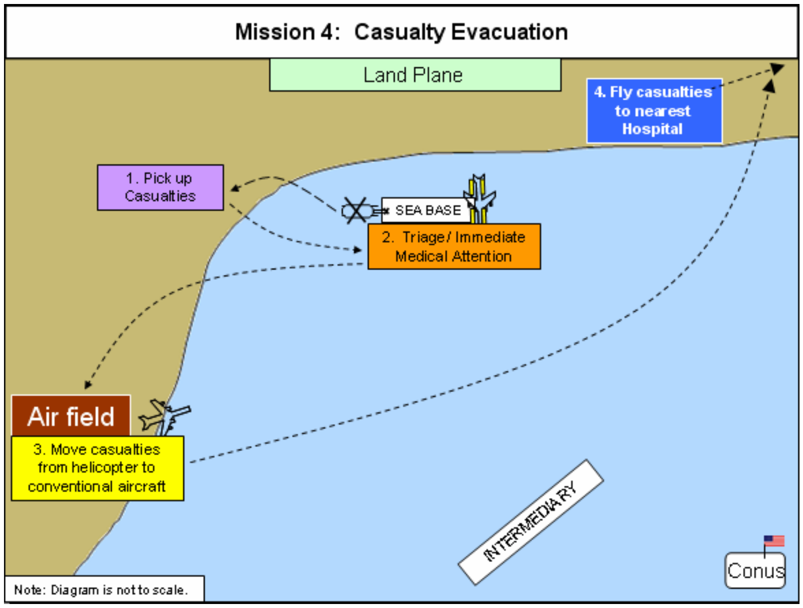

Figure 30: Casualty evacuation event model: landplane

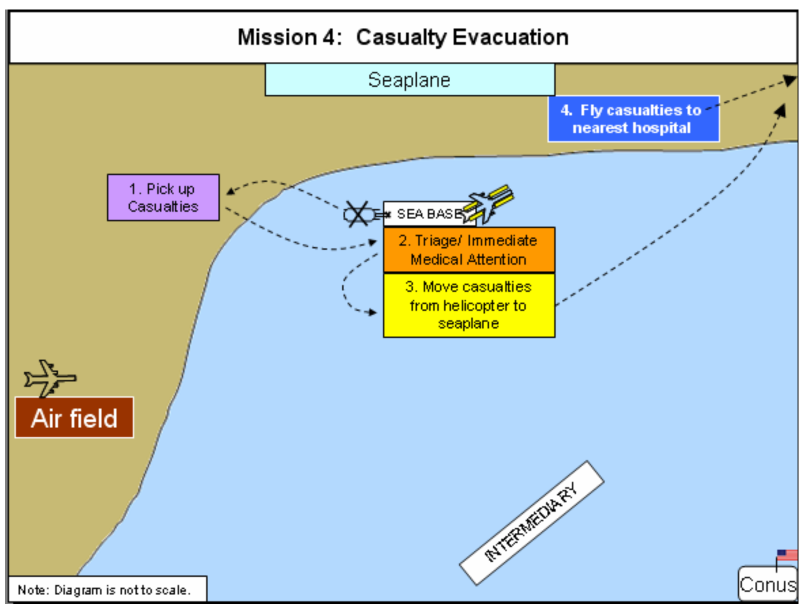

Figure 31: Casualty evacuation event model: seaplane

The casualty evacuation mission was defined as the transfer of 20 casualties from a combat area to a base by helicopter (UH-1N with 6 litter capacity) for triage and then to a hospital on land. The casualties would be located a fixed 50 nm from the Sea Base which would be 1,000 nm from the hospital. The amphibious seaplane could fly the casualties

directly from the Sea Base to the hospital. For the land plane scenario, the helicopter would have to fly to an airfield so that a C-130 could take the casualties to the hospital. The airfield was defined to be in the direction opposite of the hospital. Helicopter refueling would be done by a KC-130.

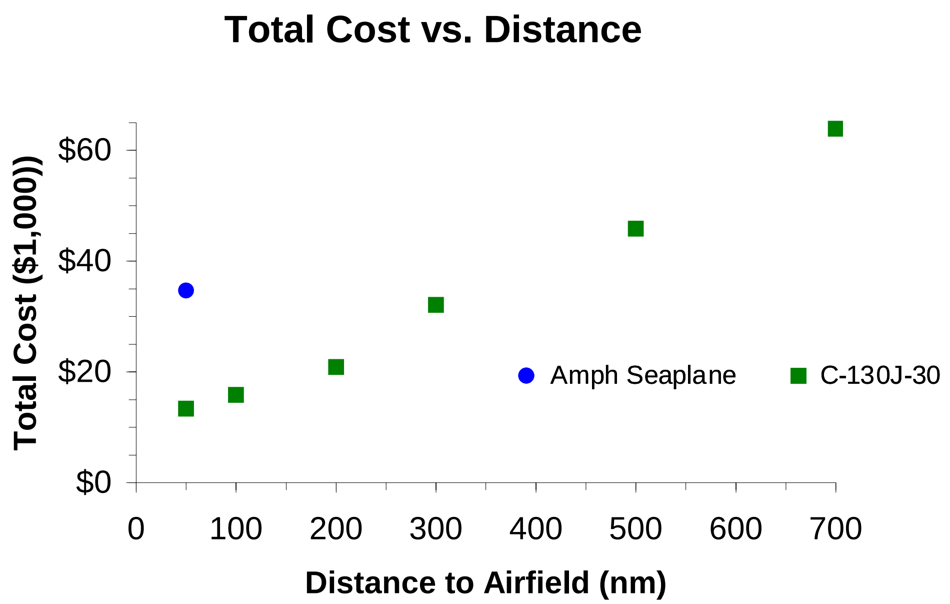

Figure 32: Total cost for casualty evacuation mission

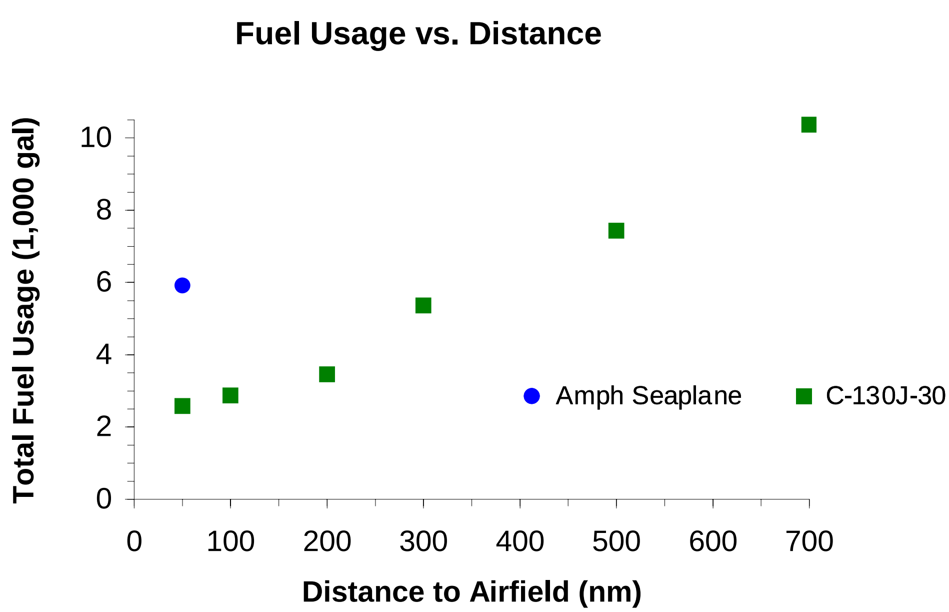

Figure 33: Total fuel usage for casualty evacuation mission

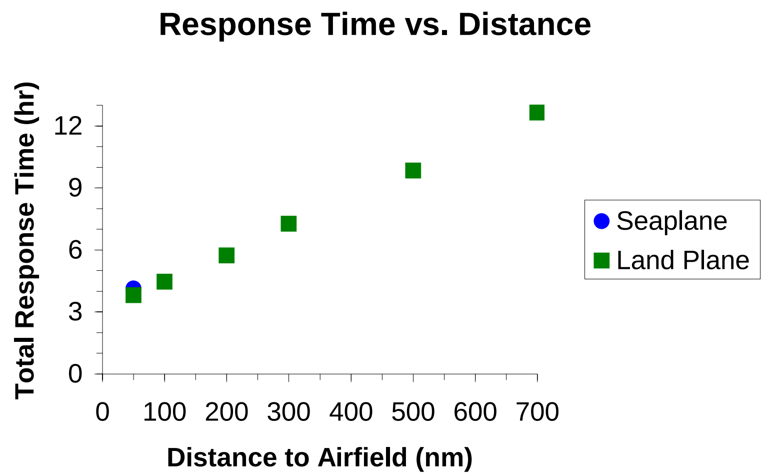

Figure 34 Response time for casualty evacuation mission

As shown in Figures 32, 33, and 34, the seaplane scenario is more economical in terms of both money and fuel for casualty evacuation if the conventional airfield is beyond the helicopter's range. More importantly, the response time is faster if this airfield is more than 75 nm from the evacuation zone.

Discussion and Conclusions

The quantitative cost comparison philosophy followed in this analysis assumed that existing conventional fixed wing aircraft would have procurement and operational costs as the major cost components. A new seaplane would have the same cost components plus developmental (R&D) costs. Contained within this philosophy is the idea that while the existing conventional aircraft have already been designed, new units would have to be procured that could be devoted to the Navy and its Sea Base operations. If it were decided to use existing cargo aircraft and pay only the hourly operational cost, the analysis would have to be changed accordingly.

An assumption also had to be made regarding the number of new seaplanes that would be built. At different times, the expected number of C-17 cargo aircraft to be procured ranged from 40 to over 200. An assumption of fifty new seaplanes was made for this study. The lifetimes that can be expected of military cargo aircraft were typically found to be around 30,000 to 50,000 hours[15]. Some of the aircraft individual components or systems may last a longer or shorter time. While the aircraft might not necessarily be retired at the 30,000 or 50,000 hours, an extension of its life would probably require an overhaul or modernization program. Such a program would involve a significant financial investment and a recalculation of the economics of aircraft costs. Therefore, 30,000 or 50,000 hours make good estimates for the economic life of an aircraft. For a future seaplane, it was assumed that the life span would be 30,000 hours. This lower number was chosen to reflect the difficulties of operating in a salt seawater environment, possibly exacerbated further by warm tropical temperatures. However, this could be addressed using materials such as titanium and composites.

These elements do represent a risk in the economic analysis performed in this study. Developmental costs are difficult to predict. The Navy has not designed a new seaplane for decades. Interpolations were made using data from recent conventional cargo aircraft. Assumptions were also made regarding a linear relationship between costs and aircraft weights. Some data support the validity of this assumption, but major avionics features could drive costs up while not increasing aircraft weight significantly. Nevertheless, the increase in complexity of the design process applies to both seaplanes and recent conventional cargo aircraft. Therefore the figures presented in this report reflect relative cost and not absolute cost. The number of aircraft to be procured and the service life are also not certain and represent risk factors in the analysis.

Besides the uncertainties regarding seaplane developmental costs and corrosion in a salt-water environment, there are also concerns about operating a seaplane in different sea states and docking with a Sea Base. These issues could lead to additional costs not considered quantitatively in this study. In addition, it can be expected that a seaplane will be somewhat heavier and slower to operate.

Nevertheless, the conclusion of this study was that design, procurement, and operation of a new seaplane comparable in capability to a C-130J is economically justified under certain conditions. For a one hundred mile distance between the Sea Base and the supported troop location, the seaplane alternative is less expensive if the conventional aircraft operate from locations 300 to 400 or more miles away. Conservative assumptions regarding costs, aircraft weight, and service life were used for the seaplane. Additional studies could be performed to examine cost for seaplanes of different sizes. Another thing to consider is that there are many missions that can be performed by non-amphibious flying boats (force closure, in-flight refueling, maritime patrol/SAR) that could result in even greater savings.

Economics aside, there are other justifications for designing a new seaplane. Its response time would be quicker since it would usually be located closer than the landplane to the supported location. Moreover, when an airfield is not in range, seaplanes mated with a Sea Base would be the only viable high-speed option. Operating large airplanes from a carrier would involve flight deck size restrictions and would take away from valuable space that could be used for combat aircraft. Shorter flying distances would also result in less fuel consumption and the subsequent logistics advantages. Also, a Sea Base should have some type of aircraft support capability beyond just using helicopters. Interfacing conventional fixed wing aircraft with a Sea Base might require an excessive reliance on air drop at sea and some type of payload recovery operation from the water. Picking up a load from the Sea Base with a conventional aircraft would be even more difficult. Seaplanes could also perform a multitude of missions that a land plane could not such as fire fighting, submarine refueling and rescue, mine warfare, watercraft insertion, and environmental cleanup. These advantages added with possibly significant fuel and operational cost savings outweigh the risks of developing a new seaplane.

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Appendix 1: Aircraft Specifications

Land Based Aircrafts

	C-130J-30	C-141C	C-17A	C-5B	UH-1N
Gross weight (1,000 lb)	164	323	585	840	10.5
Max payload (1,000 lb)	44.0	68.7	171	270	-
Max payload (troops/litters)	128/97	200/103	102/36	-	13/6
Max speed (kts)	355	435	435	470	100
Max range (nm)	3,700	4,500	4,900	5,165	-
Range w/max payload (nm)	1,700	2,000	2,200	1,700	250

Seaplanes

	Amphibious C-130 equivalent*	C-130 float plane**	Beriev A-40	Beriev Be-103	Canadair CL-415MP
Gross weight (1,000 lb)	261	164	190	5	43.9
Max payload (1,000 lb)	44.0	44.0	22.0	0.39	6.40
Max payload (troops/litters)	128/97	128/97	-	-	-
Max speed (kts)	320	320	410	130	194
Max range (nm)	2,831	3,330	2,212	460	1,250
Range w/max payload (nm)	1,301	1,530	-	-	-

* Flying boat seaplane concept defined parametrically for this study
** Lockheed Martin concept